E/CONF.39/D/78
10 Oct.1962
ORIGINAL : ENGLISH

UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item: D.7.3

Finland

AUTOGENOUS GRINDING - A KEY TO ECONOMIC PROCESSING OF MINERALS

By R.T. HUKKI,
Professor, Institute of Technology, Helsinki,
Head of Laboratory of Mineral Dressing,
State Institute for Technical Research, Finland

Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

NOTES

1. Papers selected for inclusion in General Sessions will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

2. Papers selected for inclusion in Specialized Sessions will be available at the Conference in only one of the above official languages.

3. Summaries of all papers, as submitted by contributors, will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

4. Papers and summaries will not be available for general distribution in advance of the Conference. They will be published in advance in limited quantities only for the use of delegations of participating governments and of other authorized participants. Post-Conference publication and general distribution of the Conference Proceedings will follow United Nations practices as laid down by the United Nations Publications Board.

Autogenous grinding - A key to economic processing of minerals

by

R. T. Hukki
Professor, Institute of Technology, Helsinki,
Head of Laboratory of Mineral Dressing, State
Institute for Technical Research, Finland

Most processing of mineral raw materials includes grinding as one of the basic steps. Grinding, however, is always an expensive process. Its expense results from two major sources: the cost of the metallic grinding medium and the cost of power. Of these the cost of the metallic medium, generally rods and balls, may exceed even one half of the total cost of grinding.

In the metal mining industry, grinding is conventionally performed in one of the following two ways: 1. Crushed ore is reduced in a single stage grinding circuit consisting of a ball mill in closed circuit with a mechanical classifier. 2. Crushed ore is reduced in a two-stage grinding circuit consisting of a rod mill in open circuit followed by a ball mill in closed circuit with a classifier or a cyclone.

Autogenous grinding can be defined as a grinding process where the grinding medium and the material to be ground consist essentially of the same solid material. Autogenous grinding has been applied in practice for over half a centary, notably in the gold mining industry in South Africa [1]. The conception that other ores also, in fact most ores can be ground autogenously is slowly gaining general acceptance. Actually the economic possibilities of autogenous grinding process - by the complete elimination of the gradually increasing cost of the metallic grinding medium - are truly attractive.

(1. Jackson, O.A.E., Pebble Milling Practice at the South African Gold Mines of Union Corp. Ltd, Trans A.I.M.E., 214, 1133-1144 (1959)

Many early attempts to apply autogenous grinding in practice have resulted in failure. This is beaause too much has been expected of autogenous mills. A mill equipped with an autogenous medium can never have the same grinding capacity as the same mill equipped with a steel medium, under the otherwise same operating conditions.

Two principle fields exist in the application of autogenous grinding. The first field includes conversions of existing grinding operations from metallic medium to autogenous. The second field includes new grinding plants which from the very beginning are planned to be autogenous. This paper deals primarily with the first field.

Before the conversion of an existing grinding operation from metallic medium to autogenous can take place, the following basic points must be thoroughly analysed:

(a) The number of autogenous mills required to treat the tonnage to be ground in units of the size originally applied with metallic medium.

(b) The size of the autogenous grinding units each of which would have the same capacity as each of the original mills with metallic medium.

(c) The possibility to separate, store and feed autogenous medium.

As indicated by points (a) and (b), a conversion may be achieved by installing a number of new mills, or by retaining the original units by enlarging e.g. the diameter of these mills. The latter method described in detail by Crocker [2] is far more economical. It has the decided advantage that the conversion may be limited only to a new enlarged mill shell and a new pinion. The original mill heads with bearings, spur gear and drive with motor may be retained as such.

To get a clear conception of what an autogenous mill can do, a useful study can be made on the so-called base mill power index.

(2. Crocker,B.S., Screened Ore Used for Fine Grinding at Lake Shore Mines, Trans. A.I.M.E., 193, 499-508 (1952)

The base mill has been defined by the author [3] as a cylindrical mill, 1 meter in effective inside diameter, and 1 meter in effective inside length. The base mill power P_1 is the net power in kW that a base mill will draw. The index corresponding to any grinding operation can be obtained by solving the following equation

$$P_i = \frac{P_n}{D^{2.5} L} \quad kW \qquad (1)$$

where P_n is the net power in kW drawn by the mill in question, D its effective inside diameter and L its effective inside length, both in meters. Because the net power drawn by the mill is not generally available, the total power index and total power draft (including tumbling power plus idling power of an empty mill) can be used instead as fair approximations. In general, the idling power amounts to about 10 % of the total power drawn by a mill operated with steel medium.

By the application of the base mill power index simple comparisons become now possible between mills of different sizes, grinding with any type of medium of any specific gravity, and at any speed.

Fig. I gives a series of fundamental base mill curves for wet grinding in grate and peripheral discharge mills. These curves show the maximum power in function of mill speed that can be introduced into a base mill Ø 1 m x 1 m equipped with media whose specific gravity is given on the curves. As an example it can be seen that at a convetional subcritical speed of 80 % of the theoretical critical about 12 kW of (net) power can be drawn by a base mill equipped with steel rods and balls, about 7.5 kW with autogenous medium having a specific gravity of 4.0 and about 4.5 kW with autogenous medium having a specific gravity of 2.7. It is generally accepted that the grinding capacity of a mill is directly proportional to the (net) power draft of the mill. The relative capacities of the base mill under the three conditions cited are 100, 51 and 34 units, resp.

(3. Hukki, R.T., Fundamental Study of the Grinding Characteristics of Tumbling Mills. Proceeding of the International Mineral Processing Congress, the Institution of Mining and Metallurgy, London, 7-23 (1960)

The following examples should be illustrative of cases where a conversion of a grinding operation from metallic medium to autogenous has been affected:

(i). In a concentrator in Finland [4], an overflow mill Ø 2.5 m x 3.6 m was operated at a speed 74 % of the critical with a ball load occupying 35 % of its inside volume. Under these conditions the mill drew 290 kW. The calculated base mill total power index becomes 8.2 kW. The relatively low value of the index is indicative of two negative features, viz. of the overflow type mill and of the lower than optium ball charge.

(ii). The ball load in the mill cited above was replaced by an autogenous medium load (specific gravity 3.6) occupying 55 % of the inside mill volume. Furthermore, the pulp density was lowered so that the percent solids figure in the mill discharge pulp dropped from 60 % to 45 %.

It is generally accepted that the power draft and the grinding capacity of a mill are directly proportional to the effective specific gravity of the medium, other condtions remaining unchanged. By the effective specific gravity is meant the difference between the true specific gravity of the medium and the boyant effect of the pulp surrounding the medium piece in the mill.

By assuming that the boyant effect of the pulp inside this overflow type mill would correspond to the values given above (60 % solids = sp.gr. 1.76; 45 % solids = sp.gr. 1.48), the effective specific gravities of the two media would be:

Balls	7.8 - 1.76 = 6.04
Autogenous medium	3.6 - 1.48 = 2.12

The corresponding new power draft after the conversion should be

$$\frac{(55/100) \times 2.12}{(35/100) \times 6.04} \times 290 \text{ kW} = 160 \text{ kW}$$

The measured power draft after the change was actually 150 kW. The respective calculated base mill total power index was now 4.2 kW.

(4. Tanner, H. - Heikkinen, T.; Crushing and Grinding at Outokumpu. Progress in Mineral Dressing. Transactions of the International Mineral Dressing Congress, Stockholm, 123-138 (1957)

(iii). The same mill was changed from an overflow type mill to a grate type mill by installing an inside grate of the Marcy type. By assuming that the boyant effect of the pulp within the grate mill = 0, the maximum value for the base mill total power index could be based on the previous figure of 4.2 kW as follows:

$$\frac{3.6}{2.04} \times 4.2 \text{ kW} = 7.4 \text{ kW}$$

The measured total power draft after this change was 239 kW. The respective base mill total power index based on the original mill dimensions is 6.7 kW, or about 10 % less than the figure obtained above. It should be taken into account that due to the installation of the grate, the effective mill length was reduced by about 5 %. Furthermore, it should be natural that the boyant effect of the pulp even inside a grate mill cannot be = 0. Therefore it is only reasonable that the measured index is less than 7.4 kW.

(iv).From Fig. I it can be seen that, for a medium 3.6 in specific gravity, about 6 kW net power can be introduced into a base mill at a speed 74 % of the critical. By adding 10 % to this for a compensation of the idling power, the respective total power index based on the fundamental base mill curves checks well the measured value of 6.7 kW reported in experiment (iii).

(v).The overall end result based on the indicated conversions, first from steel medium to autogenous medium, followed by a change from overflow to grate type mill, is shown by a reduction in total power draft from 290 kW to 239 kW. Accordingly, the respective reduction in capacity should be about 17.5 % only. Part of this can still be recovered in the form of medium wear reporting in the final product. Its share was found to be about 5 % of the total tonnage ground in this case.

(vi).From Fig. I it can further be seen that the net power draft and correspondingly the capacity of a grinding unit can be increased by increasing the mill speed. The original capacity of this particular grinding operation could obviously be recovered at a speed near 100 % of the critical.

(vii).At Lake Shore in Canada [5] a group of Ø 5′x 16′overflow

---

(5. Crocker, B.C.

ball mills were changed to grate type autogenous mills grinding with ore pebbles 2.66 in specific gravity. At the same time the diameter of each mill was enlarged so that the power consumption and the capacity of each unit remained unchanged.
With the steel medium the power draft was 182 hp or 135.5 kW at a speed 83 % of the critical. The respective total power index was 10.2 kW.
From Fig. II it can be seen that about 4.65 kW net power can be introduced into a grate type base mill with autogenous medium of 2.66 in specific gravity (point A in Fig. I). With idling power included the total power index would be about 5 kW. The total number of autogenous base mills needed for an equivalent grinding operation would be in these two cases

$$\frac{135.5 \text{ kW}}{4.65 \text{ kW}} = 28.3 \qquad \frac{135.5 \text{ kW}}{5 \text{ kW}} = 27.1$$

If the length of the autogenous mill is assumed to remain at 4.8 m (= 16 ft), the corresponding diameter x would be

$$x^{2.5} \cdot 4.8 = 28.3 \qquad x^{2.5} \cdot 4.8 = 27.1$$
$$x = 2.04 \text{ m} \qquad x = 2.00 \text{ m}$$
$$x = 6'8" \qquad x = 6'7"$$

At Lake Shore the new diameter of the autogenous mills was found to correspond to 6'8" after extensive and time consuming experiments in the laboratory and in plant scale.
It is seen again that the fundamental base mill curves give a satisfactory basis for the evaluation of mill sizes in autogenous grinding.
(viii).It can further be seen from Fig. I that autogenous grinding offers very interesting possibilities within the supercritical speed range, in practice at speeds between 100 % and 150 % of the critical. Preliminary experiments conducted in pilot plant scale have indicated that wet autogenous grinding is fully possible within the said range, even under conditions such that the mill automatically forms its own semiautogenous lining of the chage within the mill (6. The grinding medium, material to be

(6. Hukki, R.T; An Analysis of the Potentialities of Autogenous Grinding Mills, Paper, presented at the 1st European Symposium on Size Reduction in Frankfurt (Main), Germany (1962)

ground, and even the mill lining consists now of the material to be ground. These experiments are being extensively continued in pilot plant scale.

\+ + +

Autogenous grinding has been applied in South African gold fields in primary, secondary and tertiary steps of grinding (7. It is therefore reasonable to expect that the autogenous coarse grinding mill can replace the conventional rod mill just as autogenous fine grinding mills have already replaced fine grinding ball mills in many plants. Such a two stage autogenous grinding system has recently been successfully tested on a large scale in Finland (8. The standard sizes of rod mills are Ø 6′x 12′and Ø 9′x 12′. Before autogenous grinding of conventional relatively coarse rod mill feed can be successfully performed, the respective primary mill should have a large diameter, at least 9′, preferably larger, and the autogenous medium should be sufficiently coarse. The fundamental base mill curves given in Fig. I can again be used for mill size evaluation.

In all autogenous grinding, large tonnages of autogenous medium are needed. In the South African gold fields, the various types of media are picked by hand(9. The technical solution is the separation of suitable size fractions by screening from the crushing circuit (10. It should be natural that medium pieces used for coarse primary grinding should be more massive than those used for fine secondary grinding. The best size range may vary from case to case. The primary medium may consist of pieces lo - 25 cm in size, the secondary medium 25 - 75 mm in size.

Crushing plants do exist where it would be difficult, if not impossible, to separate autogenous media by screening. Such a difficulty may, in an extreme case, prevent an economical conversion of the grinding plant to autogenous.

(7. Jackson, O.A.E.

(8. Heikkinen, T. - Lehtonen, E.; Uber Versuche mit zweistufiger autogener Mahlung in Outokumpu, Erzmetal 402-407, (August 1962)

(9. Jackson, O.A.E.

(10. Crocker, B.S.

Storage of the separated medium should take place in silos of suitable size. Feeding of the medium from a silo to grinding units may be continuous or intermittent.

At Lake Shore [11], the conversion of a Ø 5′x 16′mill to a Ø 6′8" x 16′mill was achieved at a cost of $ 5050 per mill (1952). To this must be added expenses in separation, storage and feeding of the media. In a normal case, energy consumption should remain unchanged. On the credit side are the great savings in the cost of grinding medium. All metallic medium, rods and balls, can be eliminated. Just how great the potential savings will be in a given case can be easily evaluated by any mill superintendent who well knows what he is paying for his metallic medium. He should not be surprised if, in an extreme case, the yearly saving may equal the entire cost of his mill.

(11. Crocker, B.S.

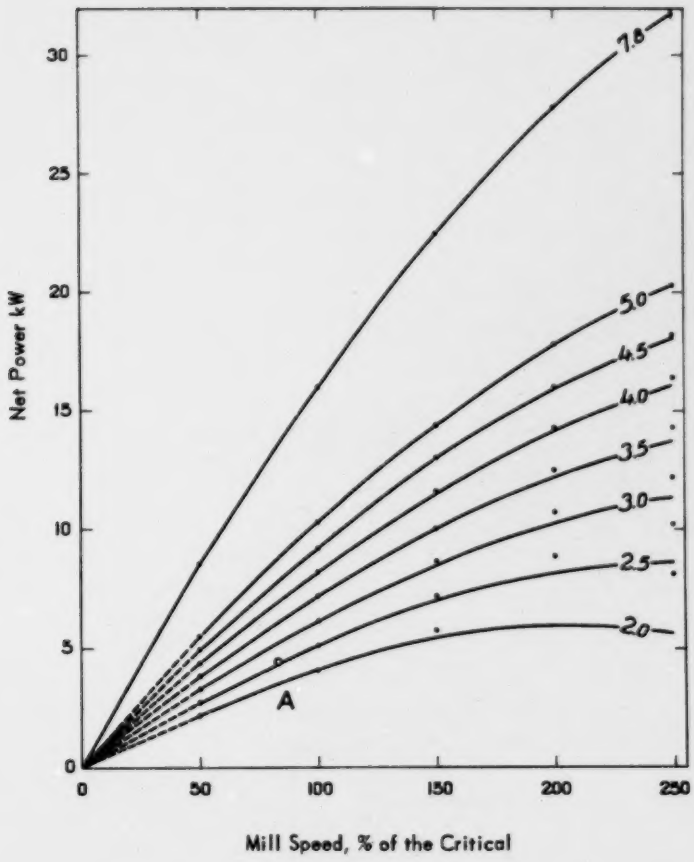

Fig. I - Fundamental base mill curves for wet grinding in grate and peripheral discharge mills

581 E - Oct.1962 - 1,600